EnergyVille

Demand Response as Flexibility Provider:

what are the challenges to achieve its full potential?

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Febeliec Workshop on Demand Response

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KU LEUVEN

Introduction: growing share of variable generation

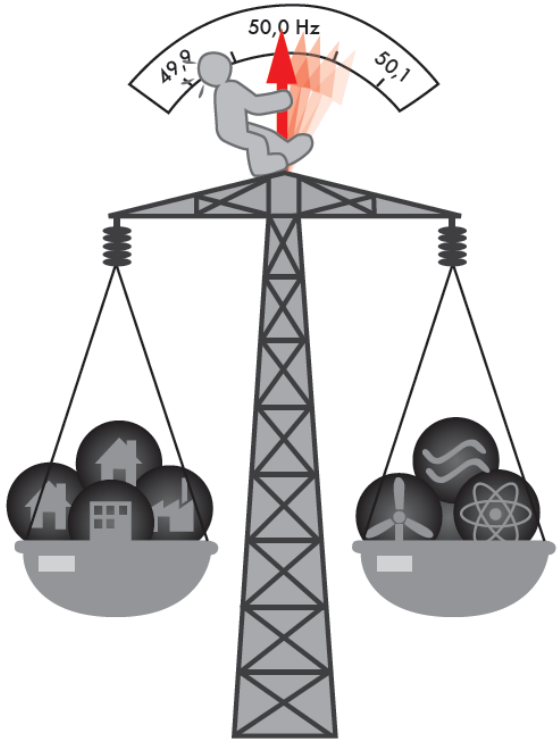
Table 1: Installed capacity (GW) and annual electricity generation (TWh) of wind and PV in selected European countries by the end of 2013 (based on data published by ENTSO-E 2015)

	wind				solar (mostly PV[3])			
	[GW]	[TWh]	penetration [%]		[GW]	[TWh]	penetration [%]	
			mean[1]	max[2]			mean[1]	max[2]
Germany	33,1	50,8	9,16	101,85	35,9	31	5,59	110,46
Belgium	1,7	3,6	4,18	27,87	2,7	2,4	2,78	44,26
France	8,2	15,9	3,21	27,70	4,4	4,7	0,95	14,86
Denmark	4,8	11	33,95	436,36	0	0	0,00	0,00
Portugal	4,4	11,7	23,78	125,71	0,3	0,4	0,81	8,57
Spain	22,8	54,7	20,89	133,33	6,9	12,8	4,89	40,35
Ireland	1,8	4,5	17,31	105,88	0	0	0,00	0,00
Italy	8,5	14,8	4,69	44,50	18,4	21,2	6,71	96,34

[1] average electric energy penetration: annual electricity generation in terms of total consumption; [2] max penetration: installed capacity in terms of minimum consumption; [3] solar in Spain includes 2.3 GW Concentrated Solar Power (CSP)

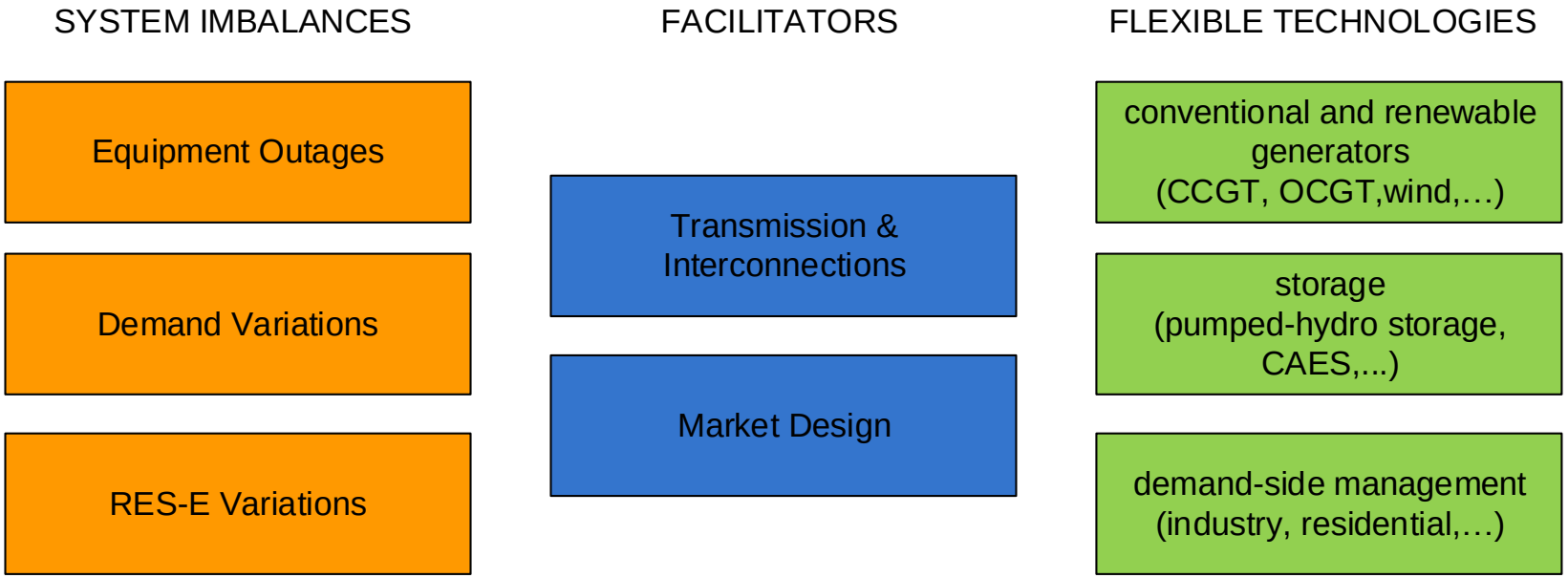
Introduction: the system need for flexibility (1)

- Real-time balance of generation and load is a prerequisite for a stable frequency level
  - Deviations from nominal frequency result in system failures, and eventually a system black out
- Up to now, variable demand has always been covered by flexible power plants
  - Generation adapts to load
  - Flexible gas-fired power plants
- Increasing penetration of variable renewable generation
  - Replacing controllable by variable supply
    - Periods with excess or shortage energy
    - Prediction errors



NEED FOR ADDITIONAL AND ALTERNATIVE MEANS FOR FLEXIBILITY!

Introduction: the system need for flexibility (2)

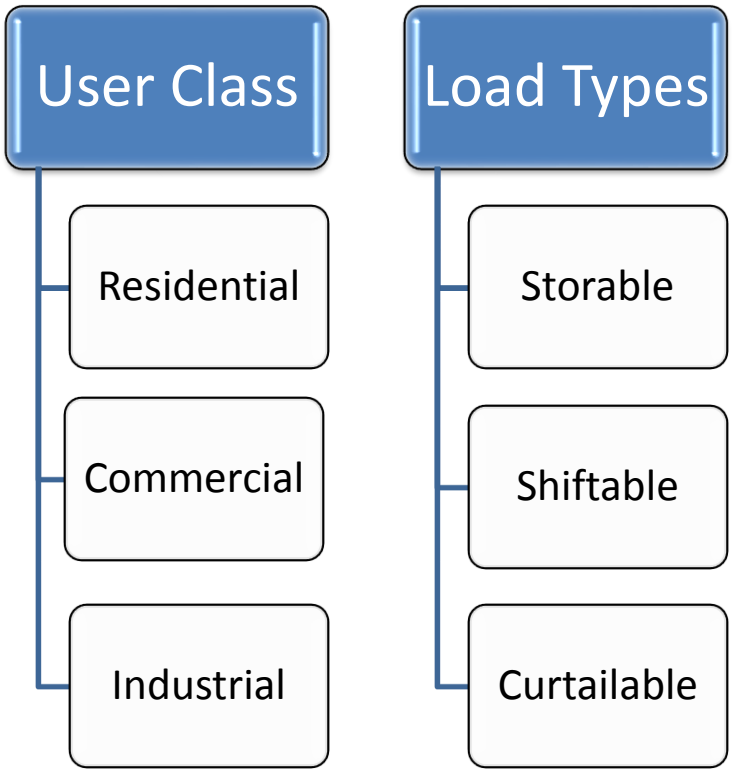


- Need for demand response is to be seen in broader context
  - Technology and cost evolutions of demand response
  - Evolutions competing technologies
  - Power system evolution: supergrids and smartgrids

Introduction: Demand Response

Definition:

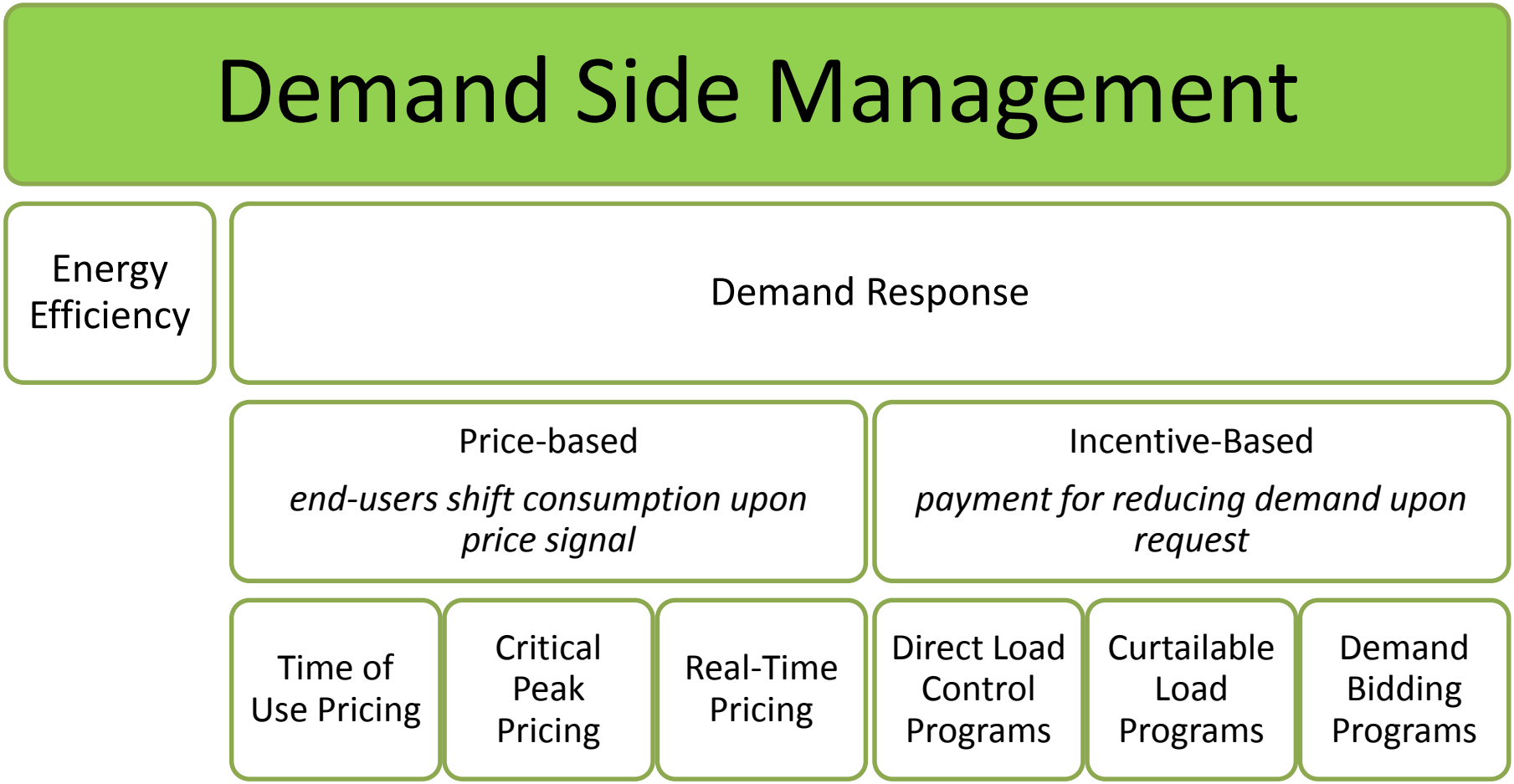
- Change in electric usage pattern of end-users
- In response to price signals or incentive payments



Increasing relevance due to:

Balancing variable generation requires flexible resources	Efficient way to cope with occasional peaks in demand	Market reform: liberalization and unbundling	Cost reductions in telecom, control systems and computation

Demand Response Categorization



Dupont, 2015

Scope and objective

CONTEXT

Variability of Renewable Energy Sources:
wind and photovoltaics

Need for flexibility:
power plants, demand response and storage

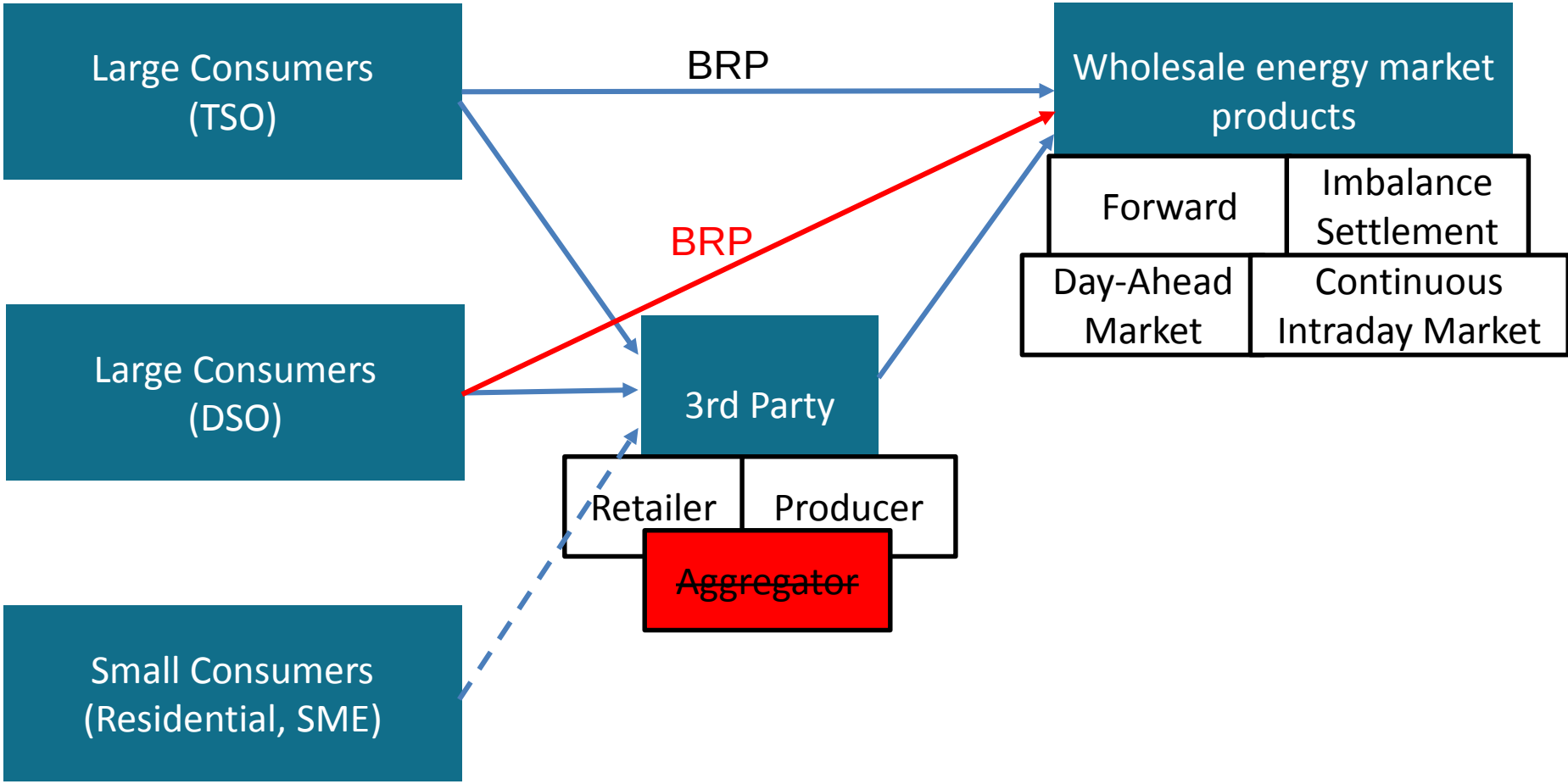
European electricity system:
interconnected transmission grid and market integration

Objective 1
The status of Demand Response in Belgium

Objective 2
The potential applications for Demand Response in the electricity market

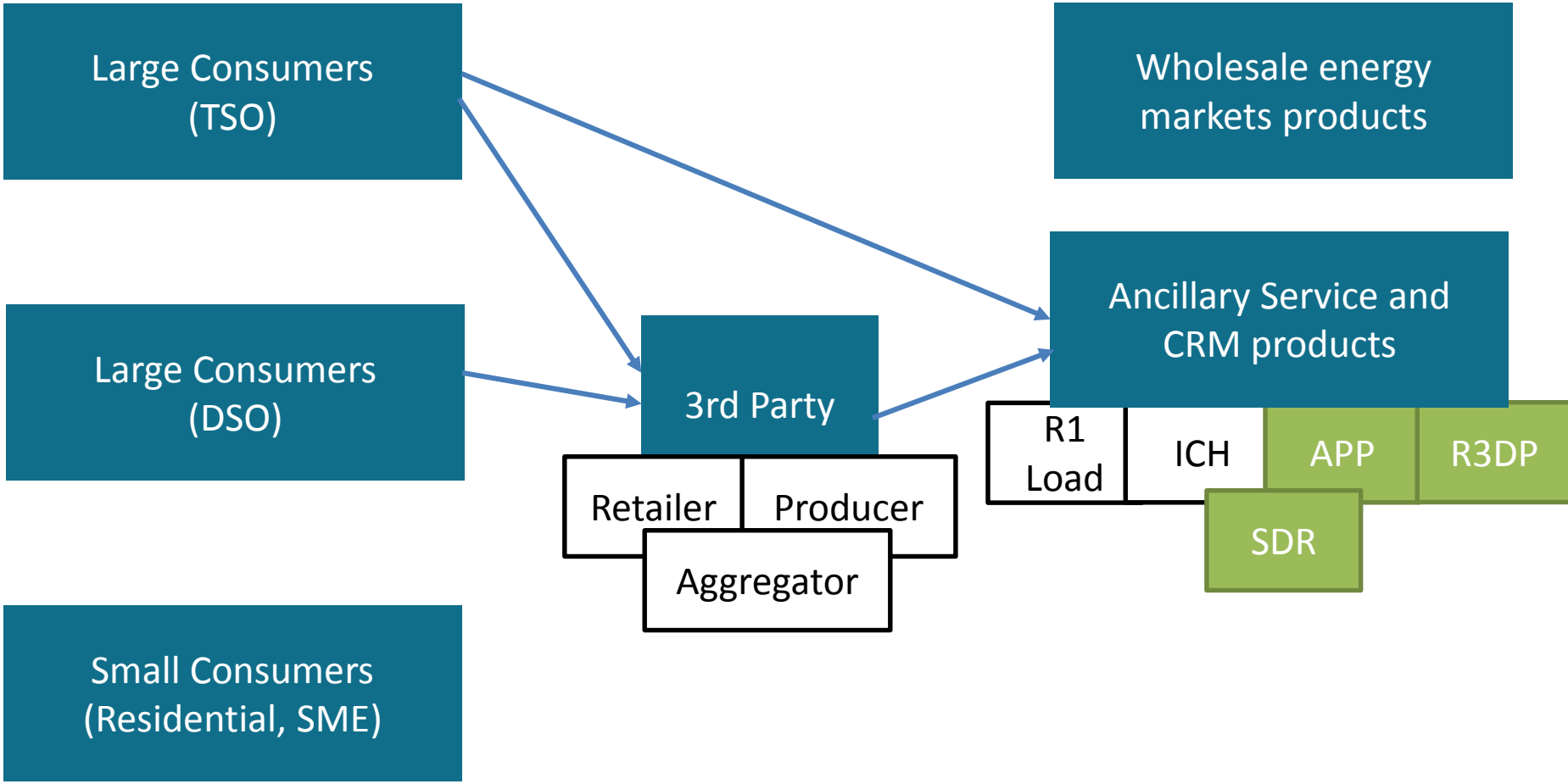
Objective 3
The system need for Demand Response

Context: demand response in Belgium

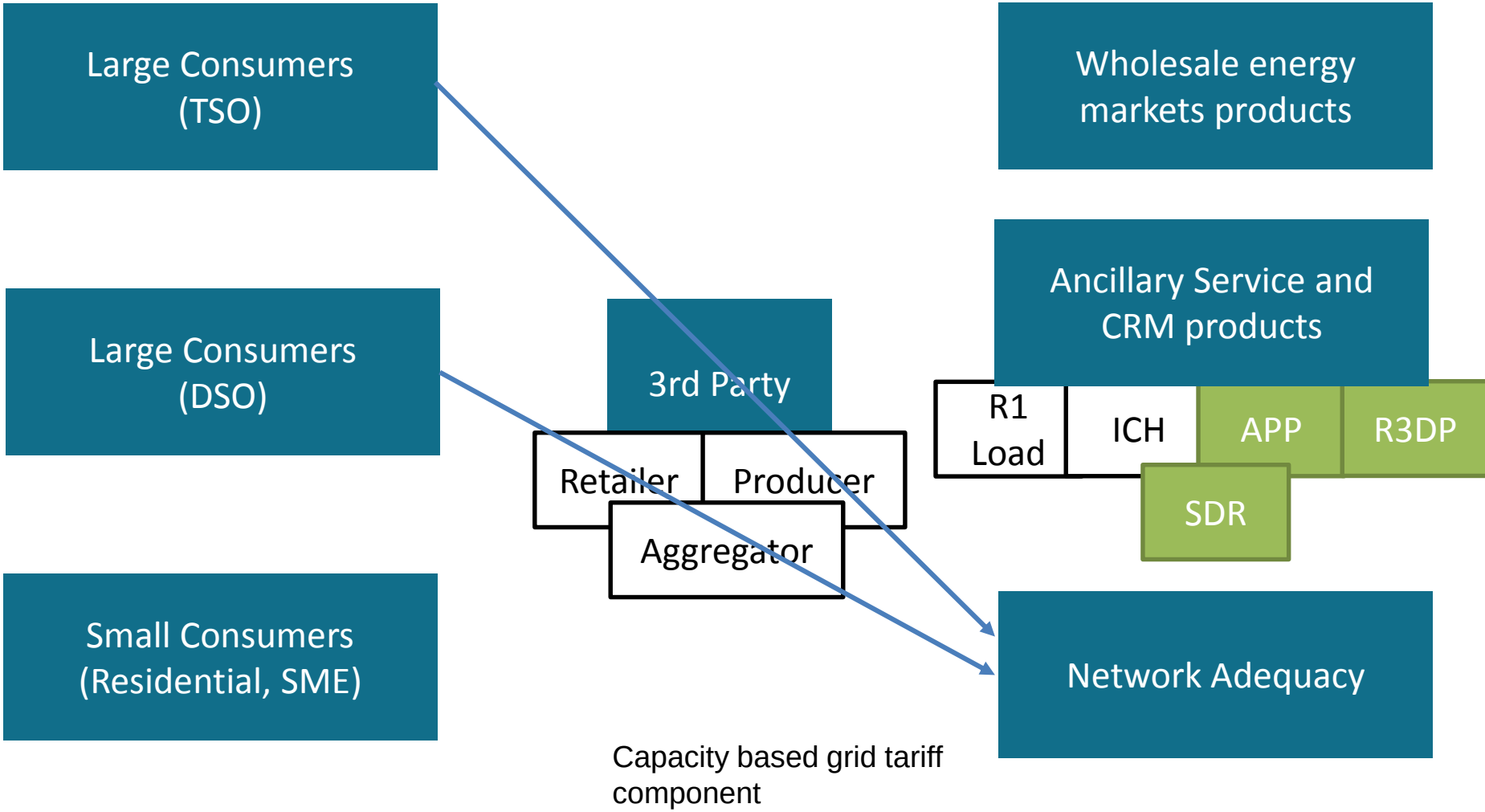


Day-Night/Weekend / Exclusive Night

Context: demand response in Belgium



Context: demand response in Belgium



Context: International Comparison (Cigré WG)

- Direct wholesale market participation for consumers is possible where markets are liberalized (but with strong entry barriers for smaller consumers).
- Ancillary service participation is generally limited to interruptible demand contracts with large industrial consumers (cfr. ICH).
- Most countries have rudimentary ToU schemes for residential consumers. Some countries' regulatory framework is less stringent towards dynamic pricing or advanced Time Of Use pricing schemes (e.g. UK and US), but lack technical infrastructure.

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Current applications of demand response

Energy services: generators and suppliers

+ Electricity market revenues
+ Operational and investment cost power plants
+ Cost-efficient integration of renewable energy in portfolio

Network services: system operators

+ Operational and investment cost network
+ Reliable and cost-efficient integration of renewable energy in the system

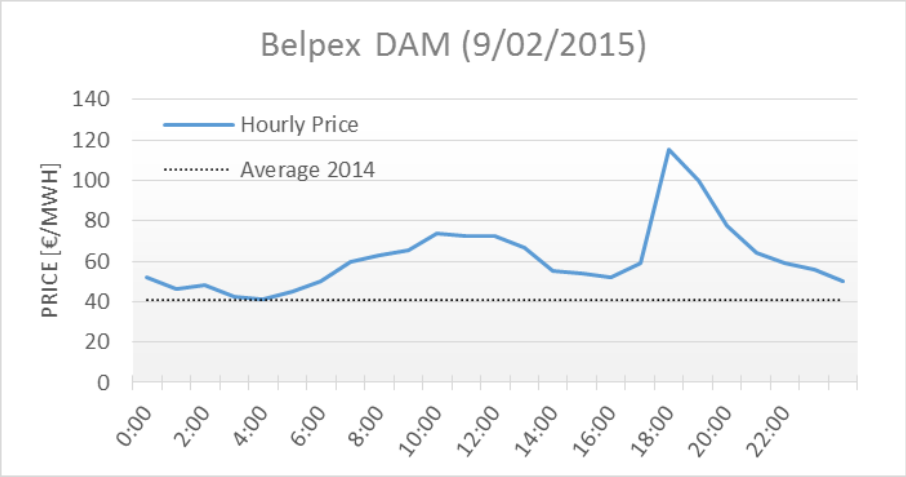
Capacity Services: consumers

+ Investment cost peak power plants
+ Cost-efficient Security of Supply

Energy Services: arbitrage (1)

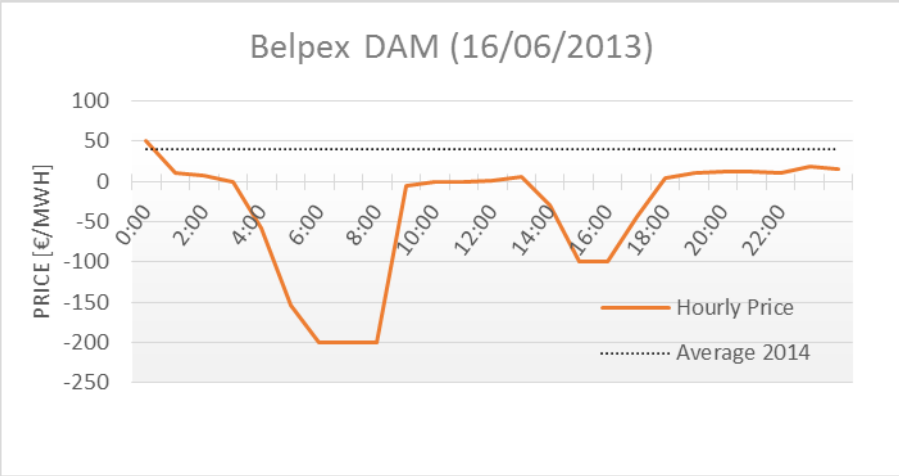
Arbitrage

- Decrease consumption in peak price period
- Increase consumption around peak price period

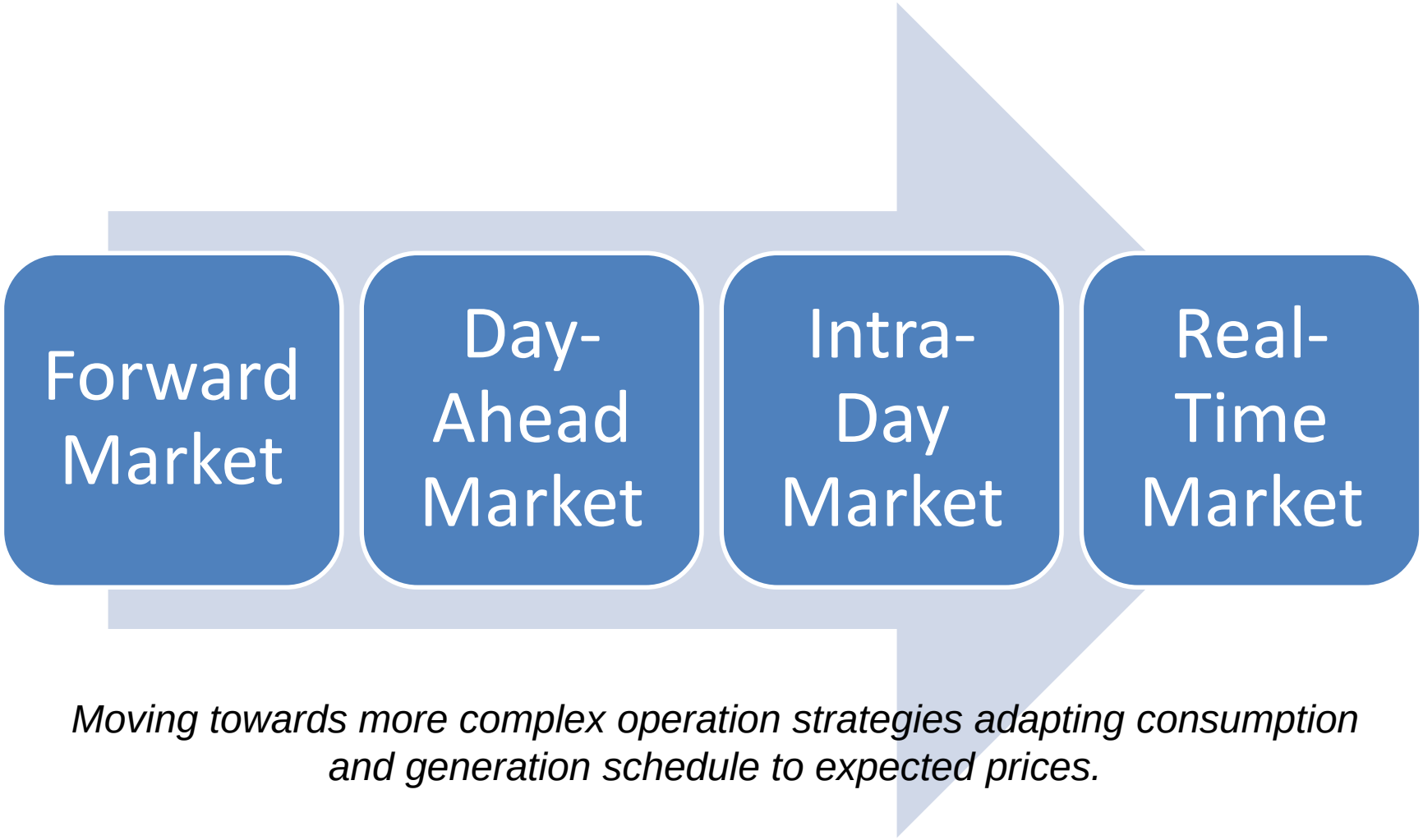


Price Forecast Tools

- Increasing complexity following variable RES moving away from fixed peak and off-peak periods



Energy services: arbitrage (2)



Moving towards more complex operation strategies adapting consumption and generation schedule to expected prices.

Energy services: portfolio management (1)

Long term

- Portfolio investments
  - Demand scenario
  - RES scenario
  - “Make or buy” decision
- Optimize portfolio investments
  - E.g. avoid investment in gas-fired power plants to cover peak demand and renewable injection.

Medium term

- Portfolio scheduling
  - Predicted RES
  - Predicted demand
  - Availability power plants
- Optimize generation schedule
  - E.g. avoid start-up of an expensive peak power plant

Energy services: portfolio management (2)

Stroom kan vrijdag uitvallen door zonsverduistering

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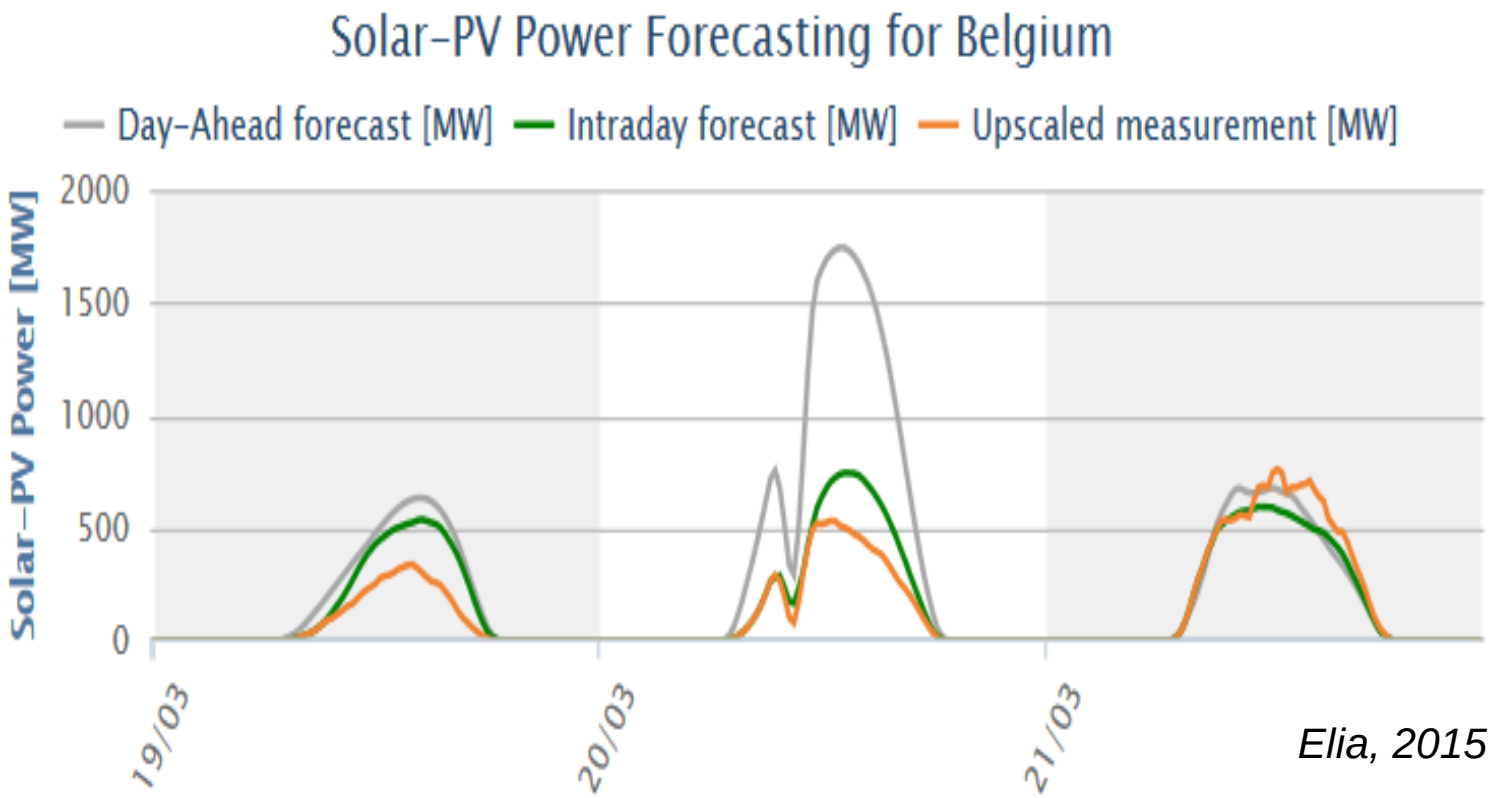

Elia, 2015

Energy services: portfolio management (3)

Short term

- Real-time portfolio balancing
  - Prediction errors RES
  - Prediction errors demand
  - Unexpected outages
- Optimize real-time portfolio balance
  - E.g. Avoid the start-up of peak power plant or imbalance price risk.

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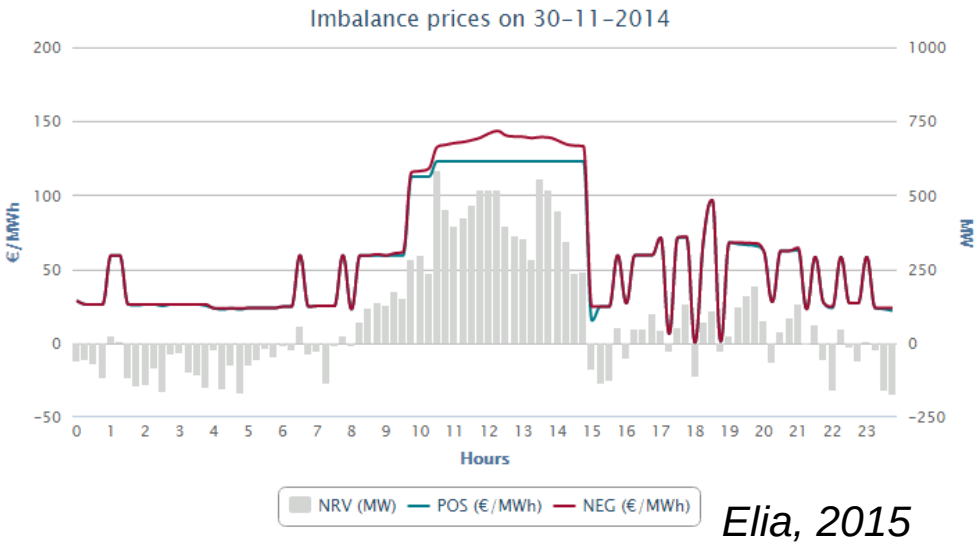


Elia, 2015

Energy services: challenges

Direct market participation

Large consumers or portfolio's
➔ entry barriers related to scale (participation fees, market framework)
➔ regulatory framework for DSO connected consumers

Indirect participation

Third Market Party: retailer
Usually Price-Based (voluntary)
➔ Regulatory framework for SMEs and Residential Sector

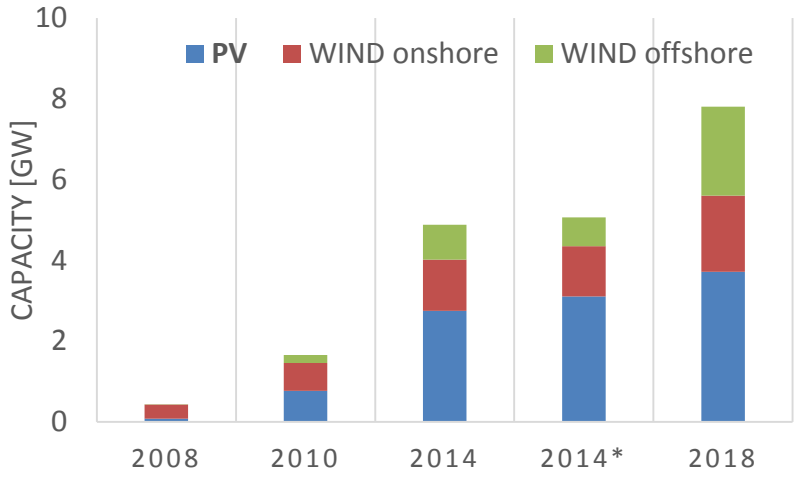
Remaining Challenges

- Deployment of metering, communication and control
  - Cost-efficiency – Market Design - Standardization
- Estimation of consumer price elasticity
- Estimation of economic value of demand response
- Consumer education
- Adoption of regulation to allow dynamic pricing schemes

Network Services

Increasing need for Operating Reserves due renewable energy integration

- Statistical Approaches to determine the need.
- Elia Study: Need for Ancillary Services towards 2018 (May 2013)
  - Increasing FFRa due to increasing intra-hourly volatility of imbalance.
  - Limited upward FRRm despite RES prediction errors (market balancing responsibility).
  - Increasing downward FRRm due to NEMO interconnector (potential loss of export capability).
- Real-time balancing needs are expected to increase despite intra-day markets and forecasts (market or TSO).



**Ex post verification*

[MW]	2014	2018 low	2018 high
FCR (R1)	95	95	110
FRRa (R2)	140	152	192
FRRm down (R3)	695	1138	1331
FRRm up (R3)	1120	1078	1321

Elia Study , 2013

Network Services: demand response products

R1 Load (30 MW)

FCR product (primary reserves)

TSO level, aggregation possible

Tailored to industrial consumers

A. Deviation > 100 mHz

B. Frequency drops only

ICH (261 MW)

FRRm product (tertiary reserves)

TSO level, aggregation possible

Tailored to industrial consumers

A. Limited number of quick activations

B. 3 min response time

R3DP (100 MW)

FRRm product (tertiary reserves)

TSO+ DSO level, aggregation possible

Tailored to distributed load/generation

A. Limited number of quick activations

B. 15 min response time

APP

Free day-ahead bids

TSO+ DSO level, portfolio

15 min response time

Capacity Remuneration Mechanisms

Capacity Remuneration Mechanism

- Instrument ensuring adequate level of generation capacity
- Complementary mechanism besides the energy market influencing the volume and capacity through remuneration available capacity
- Additional revenue streams valuing the installed capacity [€/MW]

Belgian Strategic Reserves

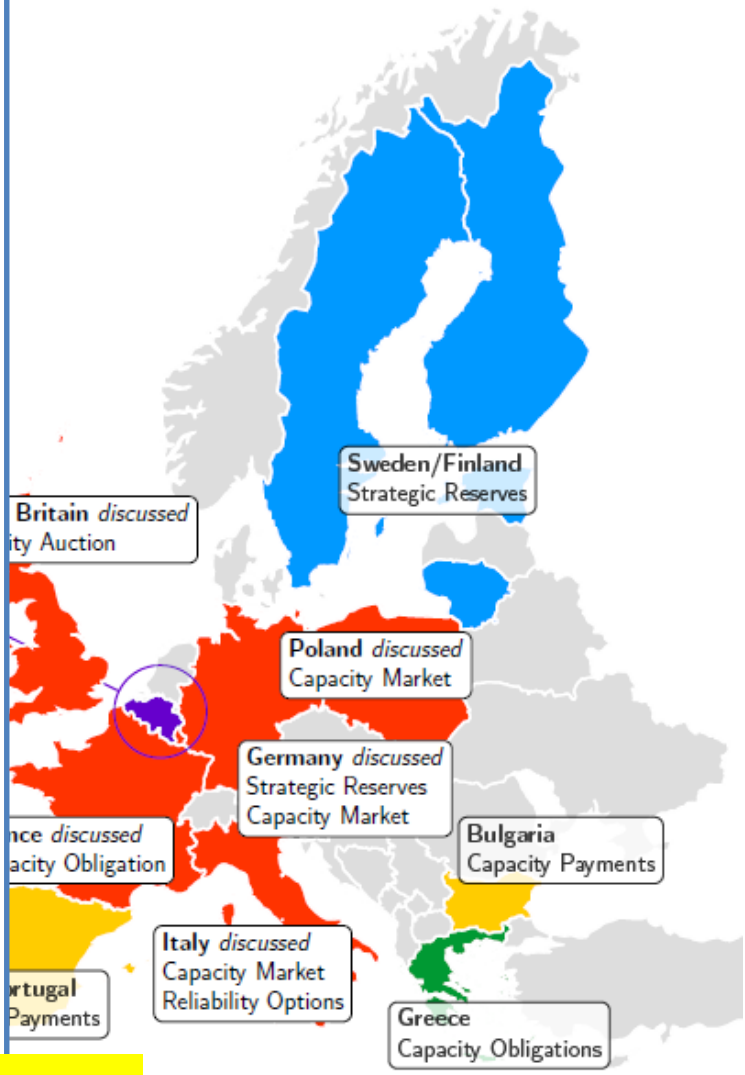
Strategic reserves in Belgium

2014-2015:

A. All production units for which closure is announced, and all units which are temporarily shut down (750 MW)
B. Demand response products (100 MW)
C. Day-ahead signal (warm up period), activation signal

2015-2016:

A. Additional 2750 MW
B. 300-500 MW from power plants (2 years)
C. Additional capacity (1 year)
D. Downward revision if Doel 3 or Tihange 2 re-commissioned



http://set.kuleuven.be/ei/fact-sheets

Network and CRM services

Direct market participation

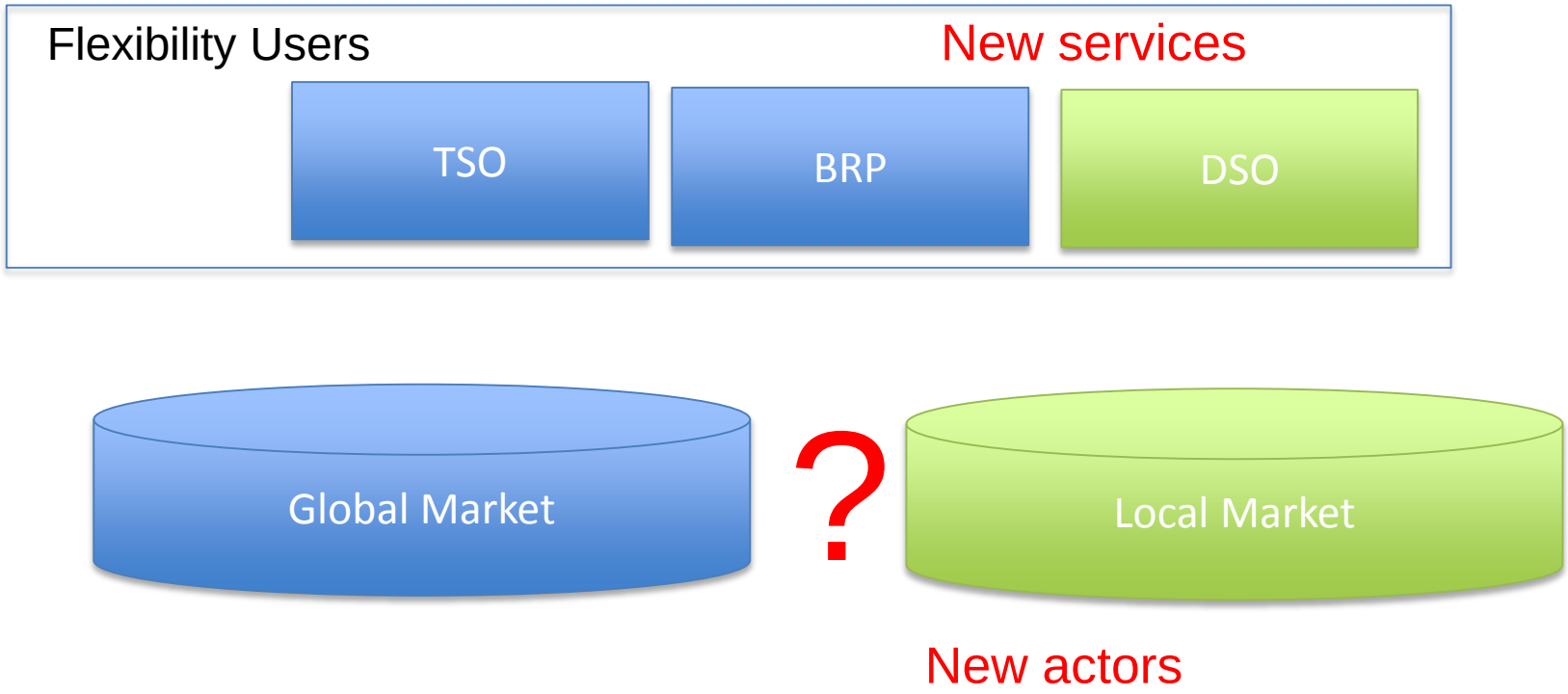
Large TSO consumers, Portfolio's
➔Entry barrier following regulated products and scale

Indirect participation

Third Market Party: Aggregator, Retailer
➔Usually incentive-based (contractual)
➔Regulatory framework (market design)

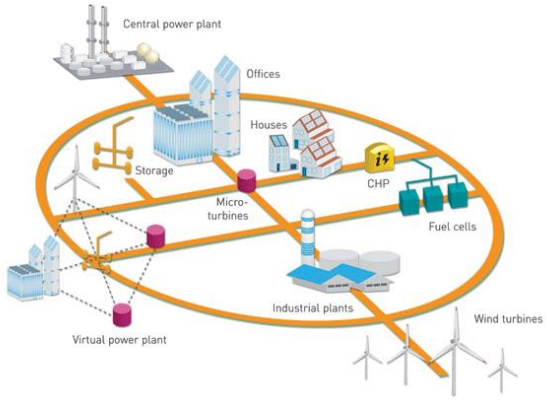
- Remaining Challenges
  - Deployment of metering, communication and control
    - Cost-efficiency – Standardization – Market Design
  - Need for a market framework on actors, roles and interactions
    - Aggregator versus BRP ⇔ TSO versus DSO
  - Consumer education
  - Energy policy which aims for a market framework with fair competition between different flexibility providers

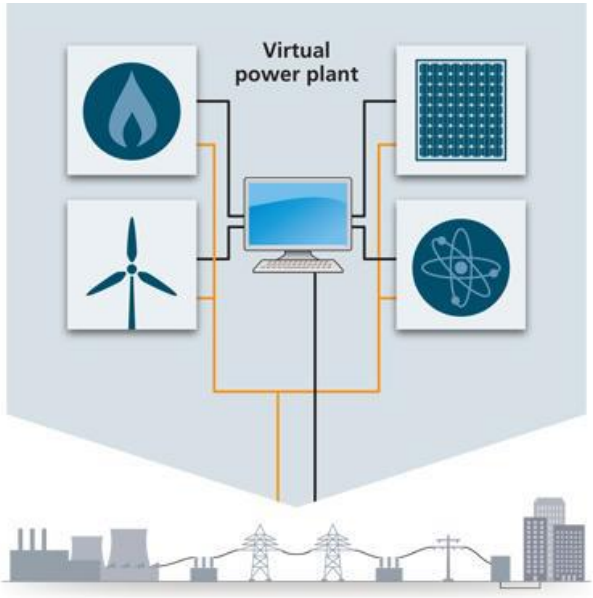
Markets for Flexibility



Virtual Power Plant

- Virtual Power Plant can be defined as:
  1. A portfolio of DERs
     - Distributed generation
     - Flexible loads
     - Storage components
  2. Operated through a control system
     - Centralized ↔ decentralized
  3. Acting as a single entity in the power system
     - Providing a range of services





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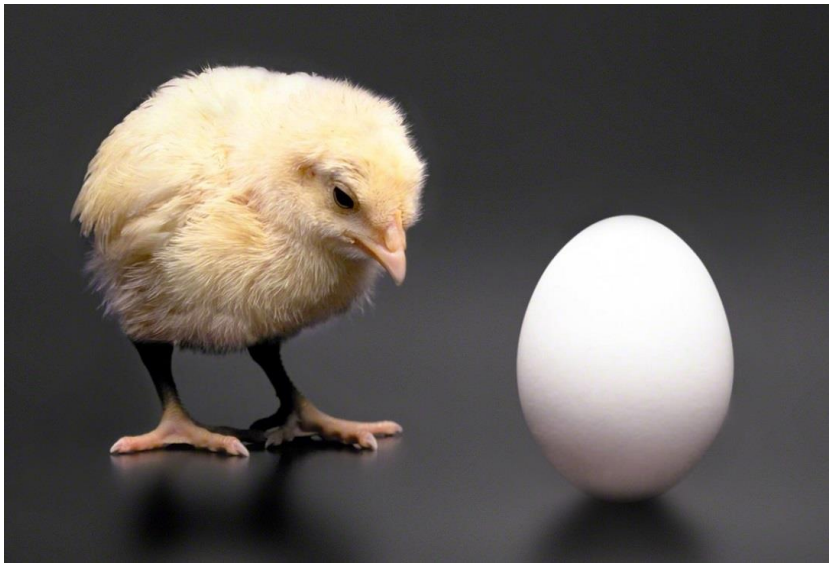
Quantification of system need for DR

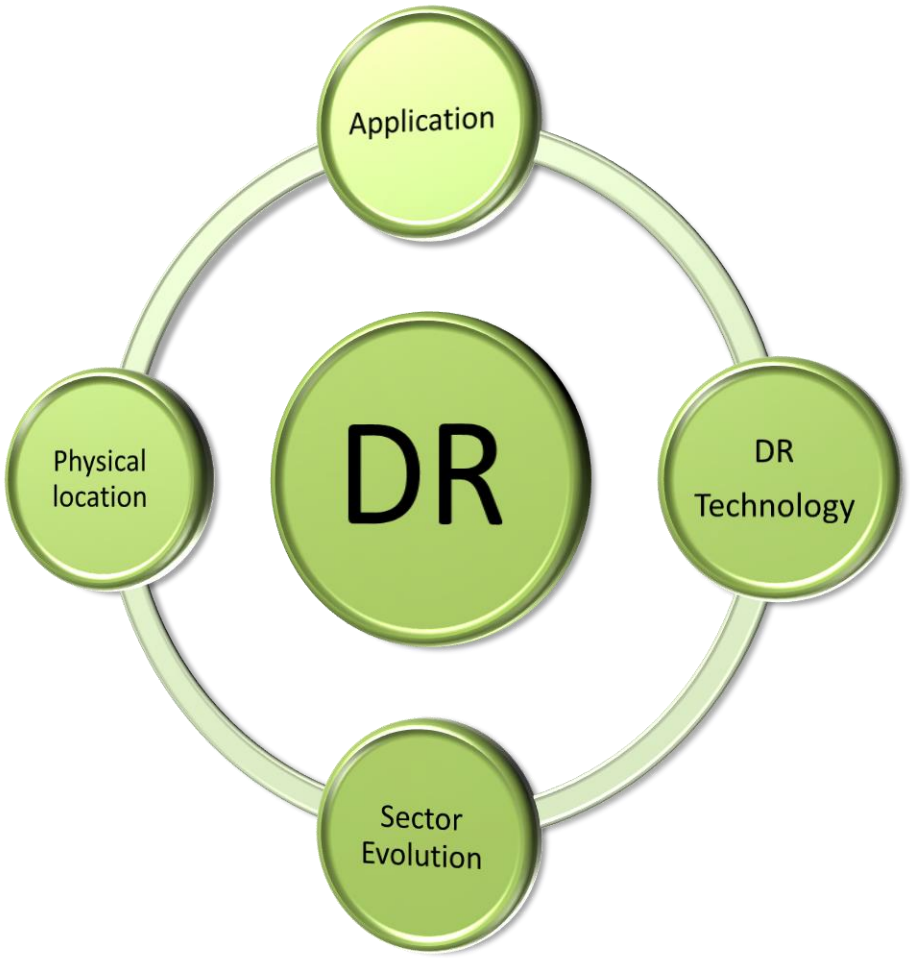
Literature: The Chicken or the Egg?

- Limited study on the need for demand response
- Limited demand response products and investments
- Limited experience on demand response value

Need for improved value assessment methodology to be developed on system level!!!



Quantification of system need for DR



- Quantification of the need for DR, or flexibility in general, is a complex problem determined by different parameters
- Integration of DR in Generation Expansion Models (operations research)
- Need for new software tools for determining future electricity market scenarios
  - Prediction errors RES
  - Power plant constraints
  - Network constraints
  - New technologies
    - Distribution level
    - Storage and demand-response

General Conclusions

1. A framework is already available for DR in Belgium, allowing participation in the energy, network and capacity services.
   A. This process started from large consumers and **is evolving towards smaller consumers on lower voltage levels,** with higher technical, economic and regulatory challenges towards system integration.
   B. The **market and regulatory framework is a key element** for the integration of DR. This framework does preferably not discriminate between different providers of flexibility.
   C. Roll-out of **measuring, communication and control equipment** is crucial for demand response but remains a technical, economic and regulatory challenge for the lower voltage levels.
2. There remains a need for a quantitative study towards the need for flexibility on long, medium and short term. This should be complemented by an analysis of DR potential.
3. The distinction between generation and load is gradually eroding. Grid users are evolving towards "PROSTUMERS" integrating generation, storage and demand response technologies.

Remaining Challenges

General Challenges

- Deployment of measuring, communication and control equipment
- Determining system needs and economic value
- Consumer education
- Coherent energy policy towards flexibility

Challenges Incentive-Based DR

- Benchmarking “energy-not-used”
- Reliable control of distributed demand (real-time).
- Market Design: actors and roles
- Non-discriminative regulated market products

Challenges Price-Based DR

- Determining consumer elasticity
- Tariff regulation to allow dynamic energy prices and network tariffs

References and further reading

Selection of Relevant EnergyVille Projects:

- Linear Project: http://www.linear-smartgrid.be/en
- Elia, Febeliec, Elia, Demand Reponse Survey: Industrial DR Potential in Belgium http://www.elia.be/~/media/files/Elia/PressReleases/2013/EN/Elia-Febeliex-EnergyVille_Demand-Response-Survey-results.pdf
- E-Harbours Project: Stimulating Smart Grid Solutions in European Harbour Areas, http://eharbours.eu/
- FOD economie, middenstand en energie :*Studie inzake de mogelijkheid tot opslag van elektriciteit*:. http://economie.fgov.be/nl/modules/activity/activite_1/20150508_technical_workshop_energy_storage.jsp
- Energy Institute Factsheets on Negative Prices and Capacity Remuneration Mechanisms: http://set.kuleuven.be/ei/fact-sheets

Selection of Relevant Academic Research:

- Benjamin Dupont: Residential Demand Response Based on Dynamic Electricity Pricing: Theory and Practice, PhD, KU Leuven, January 2015
- Kristof De Vos: Impact of wind power on Sizing and Allocation of Operating Reserves, PhD, KU Leuven, April 2013
- Plancke, G., De Vos, K., Belmans, R., Delnooz, A. (2015). Virtual Power Plants: Definition, Applications and Barriers to the Implementation in the Distribution System. . International Conference on the European Energy Market. Lisbon, 20-22 May 2015.
- van Stiphout, A., De Vos, K., Deconinck, G. (2015). Operational flexibility provided by storage in generation expansion planning with high shares of renewables. . International Conference on the European Energy Market (EEM). Lisbon, 19-22 May 2015.
- Van Dievel, P., De Vos, K., Belmans, R. (2014). Demand response in electricity distribution grids: regulatory framework and barriers. International Conference on the European Energy Market (EEM14). Krakow, Poland, 28-30 May 2014.

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Questions?

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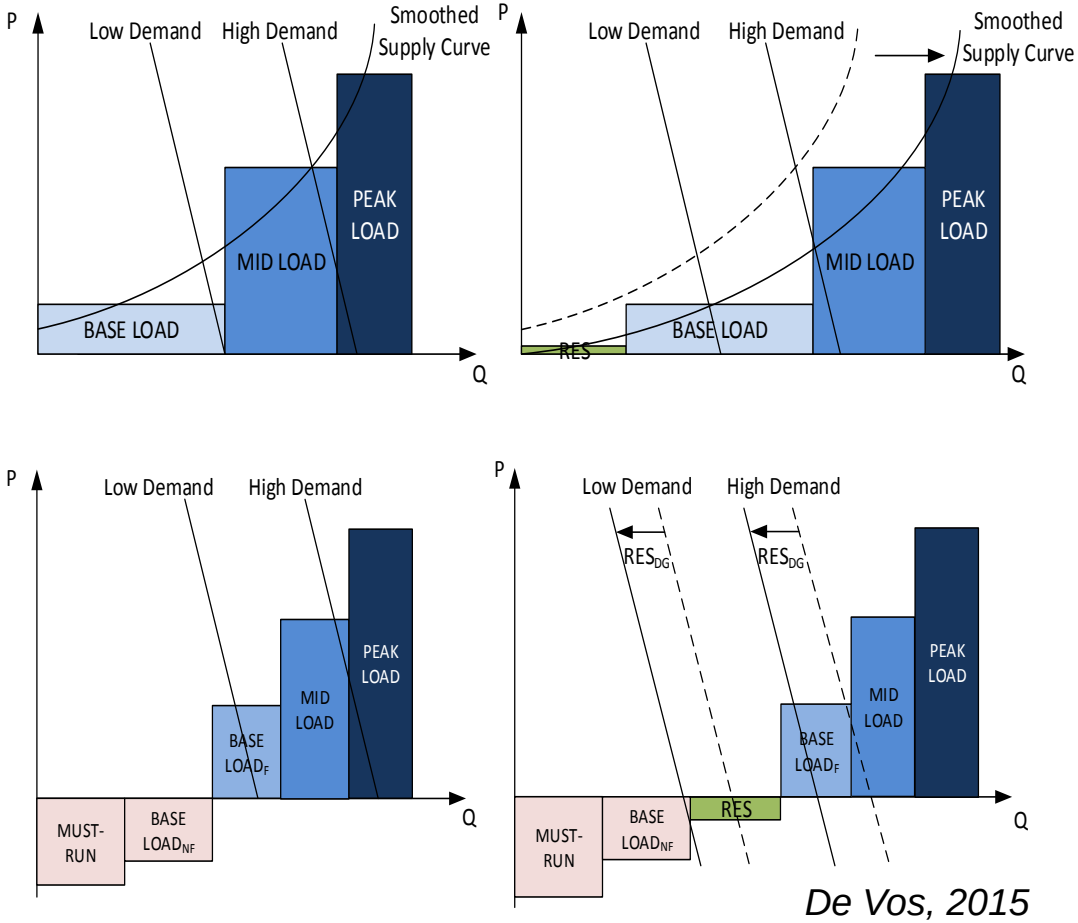
linear project: http://www.linear-smartgrid.be/en

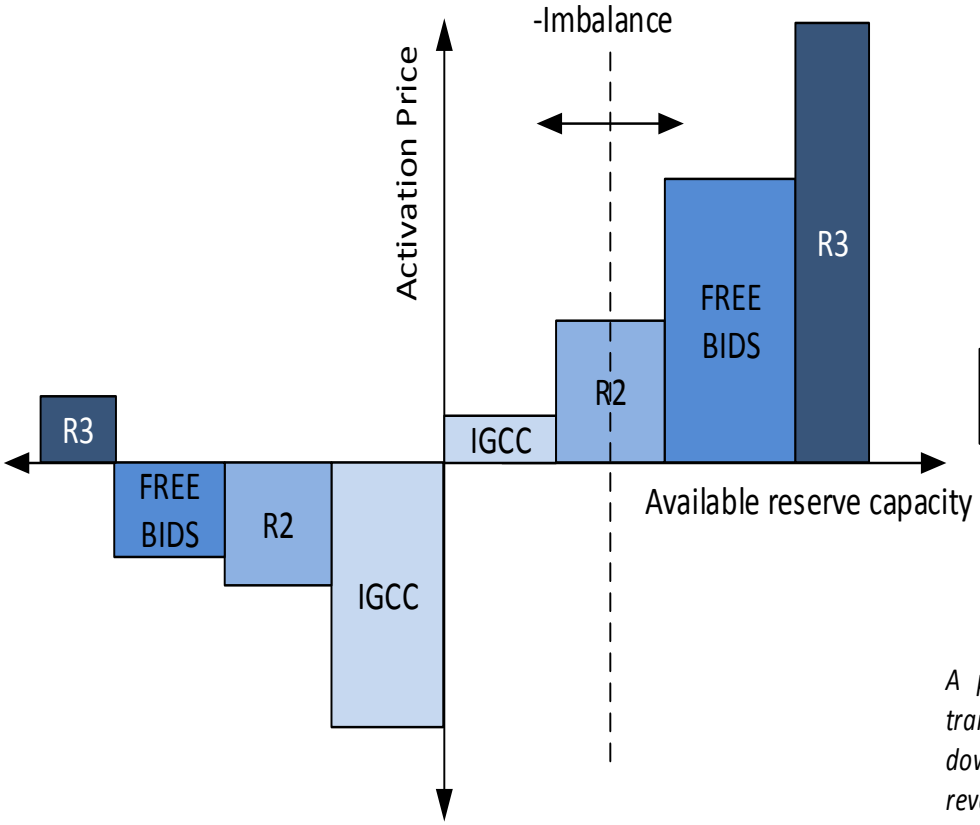
Back-up: Energy Services: arbitrage (2)

- Renewable Generation
  - Expected price volatility may change operation strategy
    - Expected Demand
    - Expected RES
    - Price forecasts
- Negative Prices
  - Must Run
  - Base Load
  - RES support
  - Priority feed-in RES



De Vos, 2015

Back-up: Energy services: portfolio management (4)



TSO

BRP	SYSTEM: EXCESS	SYSTEM: SHORTAGE
EXCESS	MDP TSO pays BRP	MIP TSO pays BRP
SHORTAGE	MDP BRP pays TSO	MIP BRP pays TSO

A positive upward activation price and negative downward activation price is translated into a positive settlement tariff (MIP and MDP). In case of a positive downward activation price, the settlement tariff is negative and money flows are reversed.

De Vos, 2015